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CODED-WIRE TAG RECOVERIES FROM PINK SALMON IN PRINCE WILLIAM SOUND SALMON FISHERIES, 1993

by

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STATE/FEDERAL NATURAL RESOURCE DAMAGE ASSESSMENT
FINAL REPORT

Project Title:	CODED WIRE TAG RECOVERIES FROM PINK SALMON IN PRINCE WILLIAM SOUND SALMON FISHERIES, 1993
Study ID Number:	Restoration Study 93067
Lead Agency:	Alaska Department of Fish and Game
Cooperating Agencies:	NOAA, UA, DNR
Principal Investigators:	Samuel Sharr Carol J. Peckham
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EXECUTIVE SUMMARY

This report documents Restoration Study 93067, one of the projects designed to restore the pink salmon *Oncorhynchus gorbuscha* resource of Prince William Sound to its pre-spill status. Coded wire tags applied in 1992 at four hatcheries in Prince William Sound, the W. Noerenberg, Cannery Creek, A. F. Koernig and Solomon Gulch facilities, were recovered in the commercial catch of 1993 and used to provide inseason estimates of hatchery contributions. These estimates were used by fishery managers to target the numerically superior hatchery returns, and thus to reduce the pressure placed upon oil-damaged wild stocks. Inseason estimates were made in two stages. Preliminary estimates were based solely on detected tags (not extracted) and were made available to managers upon completion of sampling. These estimates were then updated approximately three days later with code-specific information.

The postseason analysis revealed that out of a commercial catch of 3.51 million pink salmon, 1.12 million fish were estimated to be of wild origin. Of the hatchery component (2.39 million pink salmon), 1.1 million, 0.86 million, 0.44 million were estimated to originate from the A.F. Koernig, W. Noerenberg and the Cannery Creek hatcheries, respectively. There was no commercial fishery directed towards pink salmon originating from Solomon Gulch hatchery (contribution of 572 fish to the Prince William Sound catch) due to that facility's brood stock and cost-recovery needs. The overall adult survival rates of hatchery-reared pink salmon were 1.35%, 0.91%, 0.54% and 1.28% for the A.F. Koernig, W. Noerenberg, Cannery Creek and Solomon Gulch facilities, respectively.

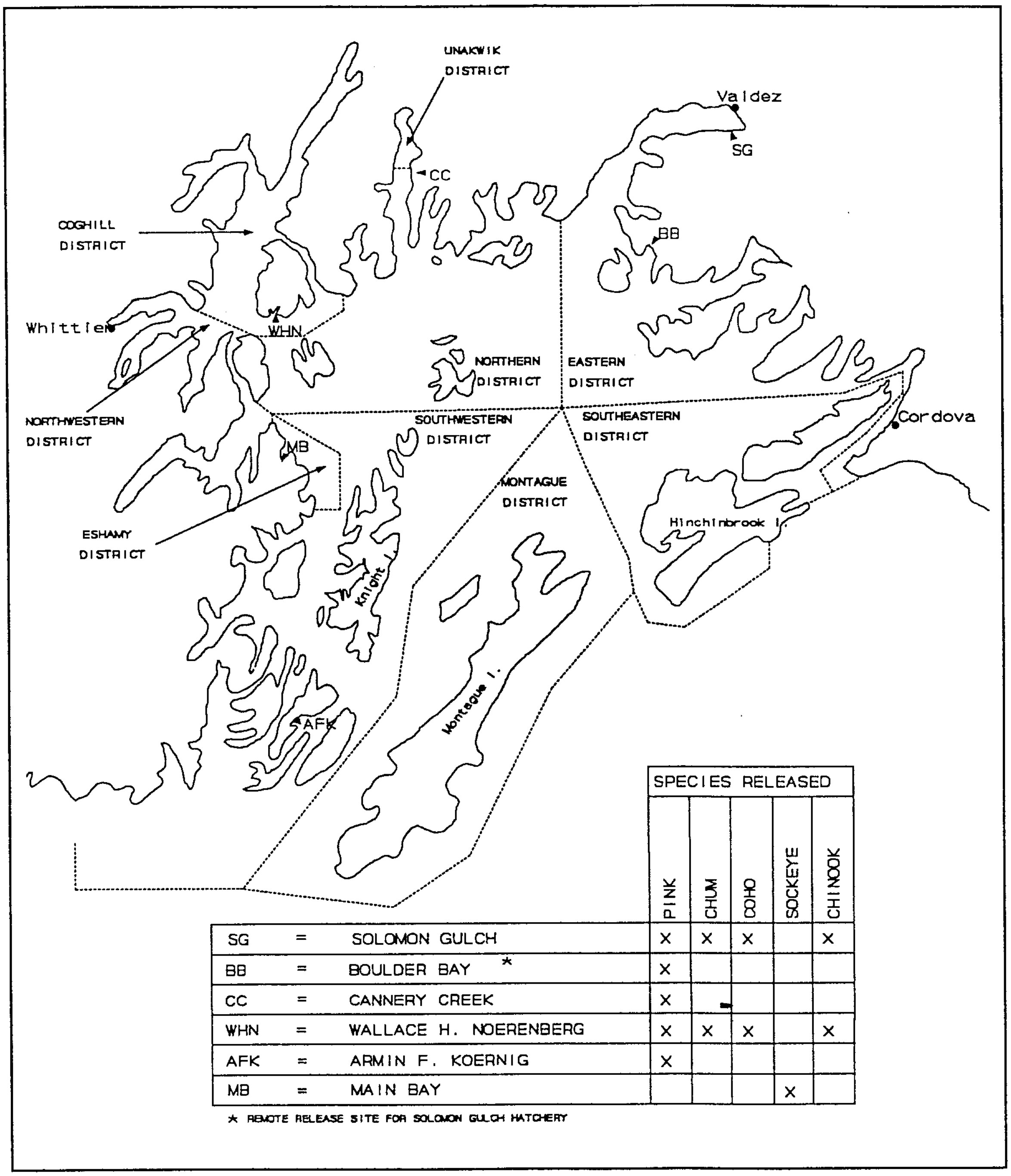
INTRODUCTION

Between 1961 and 1976, when hatcheries were absent from Prince William Sound, the commercial seine harvest of wild pink salmon *Oncorhynchus gorbuscha* averaged about 3.4 million fish. In the early 1970's, run failures led to an aggressive enhancement program which included construction of hatcheries. By 1986 five hatcheries were operating (Figure 1): the Solomon Gulch hatchery, producing pink salmon, and later, chum *O. keta*, coho *O. kisutch* and chinook salmon *O. tschawytscha*, the A. F. Koernig hatchery, producing pink salmon, the W. Noerenberg hatchery, producing pink salmon, and later, chum, coho and chinook salmon, the Cannery Creek hatchery, producing pink salmon, and the Main Bay hatchery which produced chum and presently raises sockeye salmon *O. nerka*. From the late 1980's to the present, returns to these facilities have contributed approximately 20 million fish to the annual pink salmon run. Significant numbers of sockeye, coho, chum and chinook salmon have also been produced.

Parent stocks for Prince William Sound hatchery production were selected from native populations in the Sound with the consequence that the migratory timings of adult hatchery and wild returns coincided. Furthermore, virtually all these salmon stocks migrate to their natal streams or hatcheries through corridors in the southwestern and western areas of the Sound. The coincident timing and location of the large hatchery return and the considerably smaller wild returns lead to the danger of over-exploitation of the latter by the commercial fishery. Indeed, an exploitation rate of 70% is considered appropriate for returning hatchery fish, while examination of historical data indicates shortfalls in escapements in more than half of the 15 years prior to hatchery production when exploitation rates averaged only 42%, and did not exceed 69%. Clearly, the sustainability of the wild pink salmon resource of Prince William Sound must suffer if it is subjected to harvest rates appropriate for returning hatchery fish.

To protect wild stocks in a hatchery-dominated fishery, managers needed information pertaining to the temporal and spatial distributions of hatchery and wild fish. To meet this requirement, a coded wire tagging program was initiated in 1986 for hatchery releases of pink salmon with recovery of tagged returning adults in commercial and cost-recovery fisheries beginning in 1987. Tag recovery data enabled managers to estimate hatchery and wild contributions to catches from temporal and spatial strata within the fishery.

The March 24, 1989, *Exxon Valdez* oil spill (Figure 2) exacerbated the problems faced by the fishery manager. The spill contaminated intertidal portions of streams where the majority of wild salmon stocks in western Prince William Sound spawn as well as the marine waters traversed by juvenile salmon on their migration seaward through the Sound. Natural Resource Damage Assessment Fish/Shellfish (F/S) studies 2 and 4,



			SPECIES RELEASED				
			PINK	CHUM	COHO	SOCKEYE	CHINOOK
SG	=	SOLOMON GULCH	X	X	X		X
BB	=	BOULDER BAY *	X				
CC	=	CANNERY CREEK	X				
WHN	=	WALLACE H. NOERENBERG	X	X	X		X
AFK	=	ARMIN F. KOERNIG	X				
MB	=	MAIN BAY				X	

* REMOTE RELEASE SITE FOR SOLOMON GULCH HATCHERY

Figure 1. Fishing districts and hatcheries of Prince William Sound, Alaska

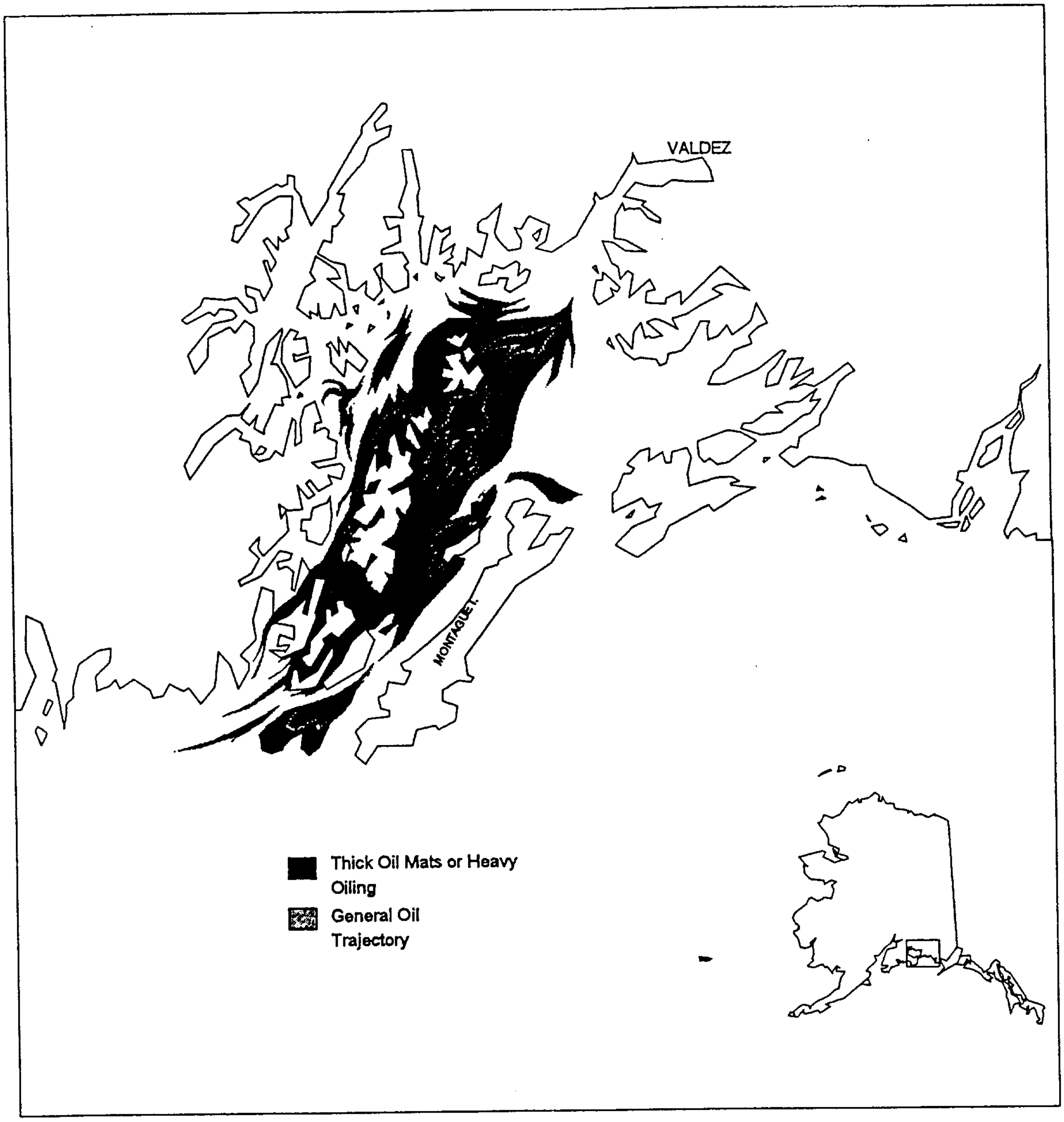


Figure 2. Trajectory of oil plume across Prince William Sound, Alaska, 1989.

demonstrated significant detrimental effects of oil contamination upon pink salmon embryos, preemergent fry, and juvenile salmon from wild populations in the Sound. The decisions made by fishery managers suddenly became more critical in as far as they affected the sustainability of wild populations, as did the need for timely and accurate catch composition estimates.

The coded wire tagging program was continued through the years following the spill, and was funded under the damage assessment study F/S 3 through 1991. During this period, the program continued to provide information pertaining to the nature of the commercial salmon catch. In 1992, the pink salmon tagging program was supported through Restoration Study R60A and in 1993 through Restoration Study 93067 (R93067) along with matching funds from the Prince William Sound Aquaculture Corporation (PWSAC), Valdez Fisheries Development Association (VFDA) and the State of Alaska. It is the activities and results of R93067 that are documented in this report.

OBJECTIVES

1. To determine the wild and hatchery components of the pink salmon commercial fisheries of 1993 and to make these available to fishery managers on an inseason basis, so that fishing effort may be directed away from damaged wild stocks.

2. To estimate marine survival rates of pink salmon released from each facility in 1992.

3. To evaluate different methods of inseason analysis of coded wire tag data.

METHODS

Tagging

Tagging of pink salmon fry occurred at the three PWSAC facilities (W. Noerenberg, Cannery Creek, and A. F. Koernig hatcheries) and at the VFDA facility (Solomon Gulch hatchery). Tagging rates and recovery efforts should yield contribution estimates which are sufficiently precise to allow fishery managers to make meaningful inseason decisions. Assuming a potential sampling rate of approximately 20% of all commercial and cost- recovery harvests and following an analysis of the performance of previous tagging studies (Peltz and Miller 1990; Peltz and Geiger 1990; Geiger and Sharr 1990), an overall tagging rate of approximately 0.00167 was chosen. A different tag code was given to each release group, a release group representing a batch of fish subjected to a certain feeding regimen (early feeding, late feeding or no feeding) and release timing. An effort was made to keep tagging rates as uniform as possible between hatcheries and between release groups within hatcheries.

Pink salmon fry to be tagged were randomly selected as they emerged from incubators. Fry were anesthetized in a 1 ppm solution of MS-222 prior to removal of adipose fins and application of tags. Half-length coded wire tags were applied with a Northwest Marine Technology tag injector (model MKII). Adipose fin-clipped and tagged fish were passed through an electronic quality control device to test for tag retention. Rejected fish were held and retested later. If rejected a second time, they were killed to minimize the number of untagged clipped fish in the release. Fry which retained tags were held overnight at PWSAC facilities and for 72 hr. at the VFDA facility to determine short-term mortality and tag-loss. Mortality rates were determined by counting the number of fish floating on the surface (floaters) after the holding period. The tag-loss rate was estimated by randomly selecting 200 fish and testing them with the quality control device before release into saltwater rearing pens. Tag placement was checked periodically, but not quantified.

At the PWSAC facilities, after the overnight holding period and prior to release, all tagged fry were introduced into saltwater pens within the larger pens holding their unmarked cohorts. This allowed determination of short-term saltwater mortalities. At the VFDA facility no saltwater mortality estimate was made because wave action at the site makes it difficult to maintain the necessary net pens. The number of fry released with tags of tag code t, Tr_t, was estimated for each release group by deducting both the short-term tagging and saltwater rearing mortalities from the number of fry initially tagged, and accounting for overnight tag loss :

$$\hat{Tr}_t = (T_t - Mo_t - Msw_t)(1 - \hat{Lo}_t), \tag{1}$$

where

T_t	=	total number of tagged (*t*) fish,
Mo_t	=	number of deaths during overnight holding period among tagged (*t*) fish,
Msw_t	=	number of deaths during saltwater rearing period among tagged (*t*) fish, and
Lo_t	=	proportion of tagged (*t*) fish that lost tags during the overnight holding period.

At the PWSAC hatcheries, unmarked fry entering the large saltwater rearing pens were enumerated with electronic fry counters. At the VFDA Solomon Gulch hatchery, the numbers of unmarked fry entering saltwater net pens were estimated from egg counts, with appropriate adjustments for egg mortality. At all facilities, pink salmon fry mortalities were estimated visually immediately prior to release. These estimates were applied equally to tagged and untagged fish to obtain final release estimates. Fry and smolt releases were timed to coincide with peak plankton abundances near the hatcheries.

Tag Recovery

Commercial and Cost-Recovery Harvests

Recoveries were stratified by district, week, and processor. This stratification was chosen as result of the findings of Peltz and Geiger (1990) who detected significant differences between the proportions of some tag codes among such strata. The differences indicate that processors tend to receive catches from only certain parts of a district and is believed to be the result of traditional tendering patterns.

Recoveries of pink salmon tags from commercial and cost-recovery harvests were made after each opening as fish were pumped from tenders onto conveyor belts at land-based processors located in Cordova, Valdez, Seward, Anchorage, Whittier and aboard a floating processor after each opening. Technicians sampled fish from the belt and subjected each to a visual and tactile examination for a missing adipose fin.

Data recorded for each tender included harvest type (i.e., commercial or cost-recovery catch), fishing district(s) from which the catch was taken, catch date, processor, and the number of fish examined. Catch data were later obtained from fish tickets.

Heads of adipose-fin clipped fish were excised, identified with a uniquely numbered cinch tag and bagged. These heads were then passed individually through a Northwest Marine tag detector which produced an audible signal upon detection of metal in the head. This procedure yielded numbers of undecoded tags in the sample.

All heads were then frozen and, together with sample data, shipped daily to the Alaska

Department of Fish and Game Coded Wire Tag Processing Laboratory in Juneau (Tag Lab). Tag Lab staff located and removed tags from heads, decoded extracted tags, and entered tag code and sample data into a database accessible to biologists in Cordova.

Brood Stock Harvests

Tag shedding from release to return and differential mortality between tagged and untagged fish lead to discrepancies between marking rates at release and recovery. Hatchery brood stocks were scanned for tags in order to estimate adjustment factors which could be used to account for the loss of tags from the population. Three assumptions inherent in the use of the brood stock for this purpose are a) the brood stock consists only of fish reared at the hatchery, b) the tendency for a tagged fish to lose a tag or to die is similar for all fish marked at the same hatchery, and c) there is no influence of an implanted tag on homing fidelity. In the current study, it was believed that the first of these assumptions had been violated at all facilities except the W. Noerenberg hatchery (see Discussion). Consequently, only the adjustment factor calculated from the 1993 brood stock from the W. Noerenberg hatchery was considered an appropriate quantity with which to adjust postseason contributions for tag loss and differential mortality.

The adjustment factor for hatchery *h*, a_h, was estimated as the ratio of sampled fish in the brood stock to the expanded number of fish based on tags found in the sample :

$$\hat{a}_h = \frac{s_h}{\sum_i^T \frac{x_i}{p_i}} , \qquad (2)$$

where

T	=	number of tag codes released from hatchery *h*,
p_i	=	tagging rate at release for i^{th} tag code (defined as number of tagged fish released with code *i* divided by the total number of fish in release group with i^{th} code),
x_i	=	number of tags of i^{th}code found in s_h and,
s_h	=	number of brood stock fish examined in hatchery *h*.

The factor is 1.0 when there is no tag loss or differential mortality, and there are no violations of the closed population assumption.

The adjustment factor was used to adjust contribution estimates (Equation 3) if it could be shown that it was significantly greater than 1.0 at the 90% level. An appropriate test of the hypothesis : $Ho : a_h \leq 1.0$ is given in Sharr et al. (1995a).

While only the adjustment factor associated with the W. Noerenberg facility was used for postseason analysis, brood stock samples were taken during hatchery egg-take operations at all four Prince William Sound pink salmon hatcheries. Technicians stationed at each hatchery examined approximately 95% of the fish through visual and tactile means for missing adipose fins. The number of fish sampled was recorded daily. When adipose-clipped fish were found, the heads were excised and shipped on a weekly basis along with sample data to the Tag Lab.

Estimation of Contributions and Survival Rates

Postseason Hatchery Contributions and Survival Rates

The contribution of release group t to the sampled common property, cost-recovery, brood stock and special harvests, and escapement, C_t , was estimated as:

$$\hat{C}_t = \sum_{i=1}^{L} x_{it} \left(\frac{N_i \, \hat{a}}{s_i \, p_t} \right), \tag{3}$$

where

x_{it}	=	number of group t tags recovered in ith stratum,
N_i	=	total number of fish in ith stratum,
s_i	=	number of fish sampled from ith stratum,
p_t	=	proportion of group t tagged,
a	=	adjustment factor associated with W. Noerenberg facility, and
L	=	number of recovery strata associated with common property, cost-recovery, brood stock, special harvests and escapement in which tag code t was found.

The contribution of release group t to unsampled strata, Cu_t, was estimated from contribution rates associated with strata that were sampled from the same district-week openings as the unsampled strata:

$$\hat{Cu}_t = \sum_{i=1}^{U} \left[N_i * \left(\frac{\sum_{j=1}^{S} \hat{C}_{tj}}{\sum_{j=1}^{S} N_j} \right) \right], \tag{4}$$

where

U	=	number of unsampled strata,
N_i	=	number of fish in ith unsampled stratum
S	=	number of strata sampled in the period in which the i^{th} unsampled stratum resides,
C_{tj}	=	contribution of release coded with tag t to the sampled stratum j, and
N_j	=	number of fish in jth sampled stratum.

When a district-week opening was not sampled at all (an infrequent occurrence), the catch from that opening was treated as unsampled catch of the subsequent opening in the same district.

An estimate of the contribution of tag group t to the total Prince William Sound return for 1993 was obtained through summation of contribution estimates for sampled and unsampled strata. An estimate of the total hatchery contribution to the Prince William Sound return was calculated through summation of contributions over all release groups.
A variance approximation for $\hat{C}_t$, derived by Clark and Bernard (1987) and simplified by Geiger (1990) was used:

$$\hat{V}(\hat{C}_t) = \sum_{i=1}^{L} x_{it} \left[\frac{N_i \hat{a}}{s_i p_t}\right]\left[\frac{N_i \hat{a}}{s_i p_t} - 1\right]. \tag{5}$$

Assuming that covariances between contributions of different release groups to a stratum could be ignored, summation of variance components over all tag codes provided an estimate of the variance of the total hatchery contribution. Inspection of the formula given by Clark and Bernard (1987) for the aforementioned covariances shows them to be negligible for large N and s, and to be consistently negative, so that when ignored, conservative estimates of variance are obtained. Variances associated with unsampled strata are believed to be small (Sharr et al.,1995a).

The survival rate of the release group coded with tag t (S_t), was estimated as:

$$\hat{S}_t = \frac{\hat{C}_t + \hat{Cu}_t}{R_t}, \tag{6}$$

where

C_t	=	contribution of release group coded with tag t to sampled strata,
Cu_t	=	contribution of release group coded with tag t to unsampled strata,
R_t	=	total number of fish in release group coded with tag t released from hatchery.

Assuming the total release of fish associated with a tag code is known with negligible error, and that the cumulative variance contributions associated with the unsampled strata are small, a suitable variance estimate for $\hat{S}_t$ is given by:

$$\hat{V}(\hat{S}_t) = \frac{\sum_{i=1}^{L} x_{it} \left[\frac{N_i\,\hat{a}}{s_i\,p_t}\right]\left[\frac{N_i\,\hat{a}}{s_i\,p_t} - 1\right]}{R_t^2}\ . \tag{7}$$

Inseason Hatchery Contributions

Two inseason estimates of hatchery contributions of pink salmon were generated for each of the openings in the western and northern portions of Prince William Sound. (There were no commercial openings in the eastern part of the Sound in 1993). The first and more timely estimate was made using the method suggested by Sharr et al. (1995b). This method depended on the number of tags (undecoded) detected in heads of adipose-clipped fish by a Northwest Marine tag scanner. Estimation using undecoded tags required that assumptions be made about adjustment (a) and expansion ($1/p_t$) factors (see Equation 3). Late-run returns to PWSAC facilities were assumed to be the only hatchery contributors to the openings in question. For those in the Southwestern district, an adjustment factor of 1.56 was used, which is a weighted average of the historical adjustment factor estimates associated with the A.F. Koernig, W. Noerenberg and Cannery Creek facilites (1.46, 1.61, and 1.78 respectively). The weighting scheme depended upon historical contributions of the aforementioned hatcheries to the Southwestern district. It is noted that at the time of inseason estimation, the extent of the problems associated with the adjustment factor estimation from the A.F. Koernig and Cannery Creek facilities were not appreciated until brood stock collection, hence the use of historical adjustment factor information from these facilities. An expansion factor of 553 was used, a weighted average of all expansion factors associated with tags released at the A.F. Koernig (556), W. Noerenberg (546) and Cannery Creek (566) hatcheries in 1992. Using a similar weighting scheme for the Coghill and Northern districts, adjustment factors of 1.64 and 1.74 and expansion factors of 551 and 553 were calculated. Calculations of inseason contributions followed those used to generate postseason results (Equation 3). A more thorough, but less timely method, used data from extracted and fully decoded tags, and allowed use of tag-specific expansion factors. While historical adjustment factor estimates were still required, knowledge of tag identities allowed hatchery-specific historical factors to be used.

RESULTS

Tagging

Pink salmon fry were released from the A.F. Koernig, W. Noerenberg, Cannery Creek, and Solomon Gulch hatcheries in 1993 (Table 1). Pink salmon were by far the most abundant salmon species cultivated and released from Prince William Sound hatcheries. Numbers of pink salmon fry released ranged from 113 million for the Armin F. Koernig hatchery to 172 million for the W. Noerenberg hatchery. Tagging rates among facilities were fairly constant and in the region of 0.00168. Solomon Gulch applied 6 tag codes, while the remaining hatcheries applied 14 or 16 codes.

Tag Recoveries

Sampling Rates

Approximately 19% of the pink salmon captured in the common property and 35% of those captured in the cost-recovery harvests were sampled during 1993. These sampling rates were functions of the magnitudes of the catch, the number of samplers and the time the fish were accessible to the samplers. The proportion of the pink salmon brood stock sampled was 94%.

Postseason Contributions and Survival Rates

Tags from hatchery-produced pink salmon were recovered in the common property, cost-recovery and brood stock harvests. Hatcheries contributed 4.84 million pink salmon (70%) to the total Prince William Sound catch of 6.93 million (Table 2). The A.F. Koernig hatchery was the largest producer among the four hatcheries cultivating pink salmon in the Sound, contributing 1.53 million fish (22%).

Survival rates (over all tag codes) of adult hatchery pink salmon were 1.35% for A.F. Koernig, 0.91% for W. Noerenberg, 0.54% for Cannery Creek, and 1.28% for Solomon Gulch (Table 3). Significant differences (α=0.05) in survival rates of hatchery-reared fish were detected between all hatcheries (P<0.0005) except for the A.F. Koernig-Solomon Gulch comparison (P=0.20). The above tests assume zero-covariance between the survival rates tested within each comparison, and that the variability associated with unsampled strata is negligible.

Table 1. Hatchery tagging data for pink salmon by facility for 1993, Prince William Sound, Alaska.

	NUMBER			AVERAGE NUMBER OF FISH PER TAG	RANGE OF TAGGING RATES
	RELEASED	TAG CODES	TAGGED		
A.F. Koernig	113,337,345	16	197,729	0.00175	(0.00163-0.00170)
W. Noerenberg	172,087,494	14	284,957	0.00166	(0.00164-0.00168)
Cannery Creek	140,030,396	14	232,526	0.00166	(0.00161-0.00168)
Solomon Gulch	141,865,235	6	235,764	0.00166	(0.00162-0.00168)

* one code at 152 fish per tag was released at the A.F. Koernig hatchery.

Table 2. Summary of hatchery and wild stock contributions to the Prince William Sound pink salmon catch of 1993 (millions of fish).

CONTRIBUTOR	FACILITY	COMMON PROPERTY	COST RECOVERY	BROOD STOCK	TOTAL CONTRIBUTION	95% BOUNDS	% OF TOTAL CATCH
Hatchery	A.F. Koernig	1.09	0.24	0.18	1.51	(1.3,1.7)	21.9
	W. Noerenberg	0.86	0.27	0.34	1.47	(1.4,1.6)	21.4
	Cannery Creek	0.44	0.09	0.22	0.75	(0.6,0.9)	10.9
	Solomon Gulch	0.00	0.94	0.17	1.11	(1.0,1.2)	16.1
	TOTAL	2.39	1.54	0.91	4.84	(4.6,5.1)	70.3
Wild stock		1.12	0.67	0.25	2.04	(1.78,2.3)	29.7

Table 3. Survival rates of pink salmon returning to Prince William Sound hatcheries in 1993.

FACILITY	SURVIVAL RATE (%)	95 % BOUNDS
A.F. Koernig	1.35	(1.21,1.49)
W. Noerenberg	0.91	(0.84,0.98)
Cannery Creek	0.54	(0.48,0.59)
Solomon Gulch	1.28	(1.16,1.39)

Adjustment Factors

Adjustment factors were estimated from pink salmon brood stocks and are presented in Table 4. The cost-recovery estimates for the Solomon Gulch and Cannery Creek hatcheries were 2.41 and 2.36. The above estimates are considerably larger than those calculated for previous years (Table 5), and the adjustment factor estimate associated with the W. Noerenberg facility was used for all contribution estimates. A justification for this decision is presented in the discussion. The W. Noerenberg adjustment factor estimate was found to be significantly greater than 1.0.

Inseason Pink Salmon Contributions

Inseason contribution estimates, using numbers of undecoded but detected tags, average tag expansions and historical adjustment factors agreed closely with post-season contribution estimates for the same district time strata.

Table 4. Adjustment factors, standard errors and *P* values calculated from broodstock data, 1993.

FACILITY	ADJUSTMENT FACTOR	STANDARD ERROR (ADJUSTMENT FACTOR)	*P* VALUE FOR Ho:A.Factor <=1.0
A. F. Koernig	2.06	0.138	0
W. Noerenberg	1.78	0.085	0
Cannery Creek	2.91	0.232	0
Solomon Gulch	3.82	0.299	0

Table 5. Estimated adjustment factors for pink salmon (1989-1993).

	Brood				Cost-Recovery	
Year	W. Noerenberg	A.F. Koernig	Solomon Gulch	Cannery Creek	Solomon Gulch	Cannery Creek
1989	1.73	1.36	1.13	2.12	1.11	1.81
1990	1.28	1.58	1.82	1.96	1.23	1.71
1991	1.82	1.45	1.94	2.28	1.55	1.97
1992	1.63	1.43	2.55	2.74	1.25	1.58
1993	1.78	2.06	3.82	2.91	2.41	2.36

DISCUSSION

Contributions of Hatchery Fish to the Commercial Catch

The coded wire tagging program was successful in providing precise postseason estimates of contributions of hatchery-reared salmon to commercial catches (Table 2). While it appears that tagging and sampling rates were adequate, the accuracy of the estimates depends upon whether certain assumptions, listed below and discussed at length in Sharr et al. (1995a), were met.

1. The tagging rate is known exactly.
2. The number of fish in the fishery (or each recovery stratum) and the number of fish in the fishery sample are known exactly.
3. The tagged sample is a simple random sample (i.e. every fish in the collection of fish has an equal probability of selection independent of every other fish in the sample).
4. All marks in a sample are observed and all tags decoded.
5. The sample of the fishery is a simple random sample.
6. The use of adjustment factors is valid.

It is believed that none of these assumptions have been seriously violated, with the exception of Assumption 6 at three of the facilities. Methods of estimation were adjusted to mitigate these findings so that unbiased contribution estimates were obtained.

The most important task of the coded wire tag program in 1993 was to provide accurate and timely inseason estimates of hatchery contributions to fishery managers. This was achieved through the method recommended by Sharr et al. (1995b), namely that preliminary estimation was based solely upon numbers of detected but undecoded tags. Inseason estimates of contribution rates were to be made available to fishery managers within 24-48 hours of the termination of the fishing period. The poor returns of pink salmon during the 1993 season did not allow extensive testing of the proposed methodology. This is not to say, however, that inseason management was not influenced by coded wire tag data. During the 1993 season, managers were faced with low escapements, a poor hatchery return, and a less-than-satisfied commercial fishing fleet which had been restricted to small subdistricts in front of the hatcheries. The decision whether to open additional areas of the Sound was a critical one, having potentially dire consequences on wild stocks on the one hand, and on the financial security of the local commercial fishing fleet on the other. Inseason data from the coded wire tagging program showed that significant numbers of wild fish were present not only in the areas in question (Figure 3), but also in the aforementioned terminal subdistricts, and that a prohibition of fishing outside the terminal areas might alleviate the wild stock escapement problem to some extent. Armed with this information, managers were able to make an informed and defensible decision to prohibit fishing outside the hatchery subdistricts. In addition, coded wire tag data were used to estimate the overall size of the hatchery return, so that an appropriate cost-recovery harvest could be determined (the hatcheries are permitted to recover 30% of their return to cover running expenses).

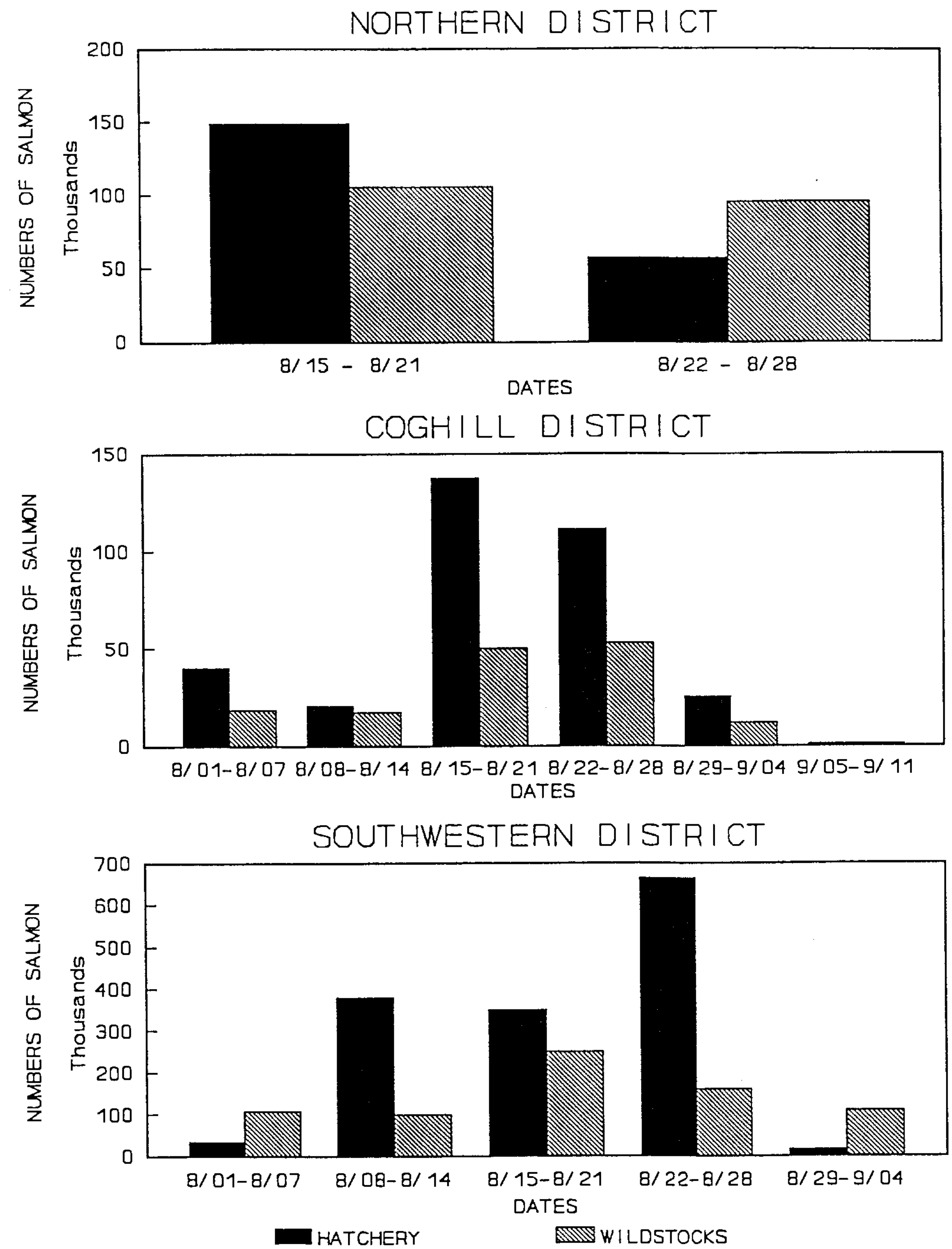


Figure 3. Pink salmon hatchery and wildstock contributions to the Prince William Sound commercial fishery by district and date.

Survival Rates of Hatchery Fish

Survival rates of hatchery reared pink salmon were considerably lower than those found in previous years. In 1991, survival rates were estimated to be between 4 and 6 % (Sharr et al., 1995a), while in 1992, they ranged from 0.94 and 2.08%. In 1993, survival rates were between 0.54 and 1.35%. The data of Willette and Carpenter (1994), suggest the hypothesis that low ocean temperatures led to reduced juvenile growth rates in 1992, and consequently to depressed survival rates of returning adults.

Adjustment Factors

While the adjustment factors calculated for the Solomon Gulch, Cannery Creek (both cost recovery and brood estimates) and A.F. Koernig hatcheries are of a different magnitude to those associated with the wild pink salmon recovery programs of 1991 and 1992 (Sharr et al. 1995a,b), they are nevertheless suspiciously large, and further, appear to be increasing with time (Table 5). For this reason, the adjustment factor associated with the brood stock of the W. Noerenberg facility was used in the estimation of all contributions. Further justification for this action is outlined below.

Large hatchery adjustment factor estimates can arise in three ways. One of these is through elevated tag loss from the population, be it through high rates of tag shedding or differential mortalities of tagged fish. If this is the cause of the large estimated adjustment factors, then the estimates should be used as determined. It is for such an event that the adjustment factor was developed. Quality control of the tagging technique has been in place at all facilities since the program's inception, however, and while it is possible that skill levels of different tagging crews may vary slightly, it is difficult to envision excessive tag shedding at some hatcheries and not at others. A comparison of tag to adipose clip ratios for different hatcheries over years supports this contention. The percentage of adipose clips containing tags for A.F. Koernig ranged from 43% to 66%, W. Noerenberg from 54% to 63%, Cannery Creek from 38% to 60% and Solomon Gulch from 63% to 81%. It is perhaps more conceivable that high adjustment factors are a result of increased differential mortality. It is possible that higher stress levied upon already-traumatized tagged fry by unfavorable ocean conditions in 1992 could cause the differential mortality rate to rise. If this is to explain the variability over the years in adjustment factors, some relationship between the survival rate of tagged fish and adjustment factors might be expected. None was found (Appendix A). Further, for consistency with the notion of an environmentally-mediated increase in differential mortality, adjustment factor estimates might be expected to be uniformly high between facilities within years. This is not the case. For 1993, the Solomon Gulch, A.F. Koernig and Cannery Creek adjustment factor estimates were high, while that for W. Noerenberg was similar to those of previous years (Table 4).

A second hypothesis to explain the large adjustment factor estimates is that the implanted tag in some way affects homing ability, so that some hatchery fish which would otherwise have homed successfully do not do so, with the result that the marking rate in the brood stock is unrealistically low. While very preliminary, some evidence has been collected to suggest that tag placement may indeed play some role in homing ability (J. Seeb, Alaska Department of Fish and Game, Anchorage, personal communication). Examination of X-rays of pink salmon heads of tagged fish that had strayed and of tagged fish that had homed revealed that a prerequisite for a fish to stray was that the tag be situated in a region that might be expected to impair olfactory function. Location of the tag in this supposedly sensitive area did not, however, appear to doom the fish to stray. It is possible that the definition of the sensitive region is not specific enough, and that tags can locate in the current region with little consequence on homing ability. To explain the observed pattern of adjustment factor estimates through effects of tag placement upon homing ability, some sort of hypothesis requiring differences in tagging placement among facilities would be needed. It has been stated above that quality control techniques exist at all hatcheries, and it is thus considered unlikely that differences in homing abilities are responsible for the large adjustment factors calculated in 1993.

The third possible explanation for the high estimated adjustment factors is that wild fish stray into the hatchery, and hence artificially reduce the marking rate in the brood stock. It is believed that this is the cause of the large adjustment factor estimates. This explanation appears to be consistent with the observed data and knowledge of the migratory habits of wild fish in the Sound. The large adjustment factor estimates were associated with the Solomon Gulch and Cannery Creek facilities, which are known to support wild spawners in their outlet channels and with the A.F. Koernig facility, which is known to lie in the migratory path of the majority of returning wild fish in Prince William Sound. The only brood stock for which the adjustment factor did not increase significantly in 1993 was that of the W. Noerenberg facility, which is distant from any major migration routes of wild fish. The straying hypothesis is also consistent with the deductions of Sharr et al. (1995a,b) in their explanation of the large adjustment factors associated with a wild pink salmon tagging program. It was concluded that large-scale straying had occurred in the tagged streams to yield the very large observed adjustment factors. Given the hypothesized purity of the brood stock at the W. Noerenberg hatchery, it was decided that its associated adjustment factor estimate be used for all hatchery pink salmon contribution calculations, regardless of the hatchery of origin of found tags. While it would be preferable to have hatchery-specific adjustment factor estimates to account for any variations in tag loss or differential mortality between facilities, it is believed that this variability is not large, and that the action taken is valid.

CONCLUSIONS

The major objective of this study was to provide fishery managers with time and location-specific data relating to the occurrence of wild stocks in the commercial fishery, and to do this in real-time with a newly developed technique based upon detected (undecoded) tags. While the poor returns of 1993 did not allow a reasonable trial of this new methodology, inseason coded wire tag data were used in important management decisions during the 1993 pink salmon fishery. In postseason analysis, reasonably precise estimates of hatchery contributions were obtained, as were estimates of hatchery survival rates.

Large adjustment factor estimates at three of the hatcheries led to a reevaluation of current contribution estimation methods.

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APPENDIX A

Relationship between Survival Rate of Tagged Fish and Adjustment Factors

The following examined the relationship between the survival rate of tagged fish and adjustment factors over years within a hatchery. Five years of data were available for each hatchery.

The Model

The following model was used to assess this relationship:

$$Y_i = \beta_o + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{1i} S_i + \beta_5 X_{2i} S_i + \beta_6 X_{3i} S_i + \beta_7 S_i + \epsilon_i$$

where:

Y_i=		i^{th} adjustment factor
X_1	=	1 if A.F. Koernig facility 0 if other facility
X_2	=	1 if W. Noerenberg facility 0 if other facility
X_3	=	1 if Cannery Creek facility 0 if other facility
S_i	=	i^{th} survival rate
ϵ_i	=	i_{th} error term, where $\epsilon_i \sim N(0,\sigma^2)$.

The model allowed the regression of adjustment factor on survival rate to vary with hatchery:

For the A.F. Koernig facility:

$$Y_i = (\beta_o + \beta_1) + (\beta_1 + \beta_4) S_i + \epsilon_i$$

For the W. Noerenberg facility:

$$Y_i = (\beta_o+\beta_2)+(\beta_2+\beta_4)S_i+\epsilon_i$$

For the Cannery Creek facility:

$$Y_i = (\beta_o+\beta_3)+(\beta_3+\beta_4)S_i+\epsilon_i$$

For the Solomon Gulch facility:

$$Y_i = \beta_o+\beta_4 S_i+\epsilon_i$$

The fitted model was as follows:

$$\hat{Y}_i = 2.79-0.89X_{1i}-0.99X_{2i}+0.15X_{3i}+0.02X_{1i}S_i+0.13X_{2i}S_i-0.08X_{3i}S_i-0.20S_i$$

Tests of significance of the null hypothesis that there is no influence of survival rate of tagged fish upon adjustment factors within each facility are given in Table A1.

There appears to be little evidence of a relationship between adjustment factors and survival rates of tagged fish.

Table A1. *P* values for tests of null hypothesis of no influence of survival rate upon adjustment factor within hatchery.

Hatchery	Parameter function tested	*P* value for H_o: Parameter function = 0
A.F.Koernig	$\beta_1+\beta_4$	0.57
W. Noerenberg	$\beta_2+\beta_4$	0.55
Cannery Creek	$\beta_3+\beta_4$	0.19
Solomon Gulch	β_4	0.106